California Regional Water Quality Control Board
Santa Ana Region

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Item: 11

Subject: Canyon Lake Nutrient Total Maximum Daily Load (TMDL) Problem Statement

California Regional Water Quality Control Board
Santa Ana Region

STAFF REPORT

PROBLEM STATEMENT FOR TOTAL MAXIMUM DAILY LOAD FOR NUTRIENTS

in CANYON LAKE

October, 2001

Executive Summary

Clean Water Act Section 303(d) requires that States identify waters that do not or are not expected to meet the water quality standards (beneficial uses, water quality objectives and anti-degradation policy) with the implementation of technology-based controls. Once a waterbody has been listed on the 303(d) list of impaired waters, states are then required to develop a Total Maximum Daily Load (TMDL) for the pollutant causing impairment. A TMDL is defined as the sum of the individual waste load allocations for point sources, and load allocations for nonpoint sources including natural background. TMDLs must also address seasonal variations and include a margin of safety. In 1994, the Regional Board identified both Lake Elsinore and Canyon Lake as impaired due to excessive levels of nutrients and other pollutants. As a result of the listing, the Regional Board has initiated the development of the Lake Elsinore and Canyon Lake nutrient TMDLs.

This report provides an overview of the Canyon Lake watershed, and a summary of past studies conducted on Canyon Lake. The report also summarizes proposed numeric targets for the Canyon Lake nutrient TMDL, as well as activities to be undertaken by Regional Board staff and other agencies to develop the nutrient TMDL and restore Canyon Lake.

There are reasons that a separate report was prepared for Canyon Lake nutrient TMDL development, although Canyon Lake and Lake Elsinore are located in the same watershed. Canyon Lake is approximately two miles upstream of Lake Elsinore, yet the two lakes are not always connected. The two lakes have very different morphologies, nutrient dynamics, and ecological structures, as well as different designated beneficial uses and water quality objectives. Therefore, a separate report was prepared for the Canyon Lake nutrient TMDL problem statement. On November 16, 2000, Regional Board staff presented the Lake Elsinore nutrient TMDL problem statement to the Board and the public. Much of the information provided in the Lake Elsinore Nutrient TMDL problem statement, particularly the watershed discussion, is applicable to the Canyon Lake nutrient TMDL and therefore will not be repeated in this report.

Regional Board staff is not proposing that any formal action by the Regional Board on the Canyon Lake nutrient TMDL be taken at this time. The intent of this report is to provide the Board and the public with background information and staff's initial strategy and ideas for development of the Canyon Lake nutrient TMDL.

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1.0 Description of Canyon Lake

Canyon Lake, also known as Railroad Canyon Reservoir, was constructed in 1928 by the Temescal Water Company. The Lake was constructed to store water from the San Jacinto River for agricultural irrigation in the area. The surface area of Canyon Lake is about 500 acres, with a storage capacity of 11,900 acre-feet. The Railroad Canyon Reservoir dam is located approximately two miles upstream from Lake Elsinore, the terminus of the San Jacinto Watershed. Approximately 735 square miles of the San Jacinto Watershed drains into Canyon Lake before reaching Lake Elsinore. During most years, drainage from the San Jacinto River watershed terminates at Canyon Lake without reaching Lake Elsinore. In the last decade, the only significant overflows from Canyon Lake to Lake Elsinore occurred in 1993, 1995, and 1998. The San Jacinto River drains to the north part of Canyon Lake, and Salt Creek, the other major tributary, drains to the east part of the Lake (Figure 1 and Figure 2). The geological and physical characteristics and land use of the San Jacinto Watershed have been previously described in the staff report "Problem Statement for the Nutrient TMDL for Lake Elsinore" (RWQCB, 2000). The majority of land in the San Jacinto basin consists of federal, state or privately owned open space areas. According to 1993 land use data from the Southern California Association of Governments (SCAG), land use in the watershed includes vacant land (66%), agricultural land (18%) that includes Confined Animal Operations such as dairies and chicken ranches and irrigated cropland, and residential uses (9%). Vacant land/open space is being converted to residential uses as the population in the area increases. However, a significant portion of open space is not suitable for development and will remain as such because the land is either Federal forest, state wildlife habitat or within the flood plain. The major municipalities in the watershed include the cities of San Jacinto, Hemet, Sun City, Perris, Canyon Lake, Lake Elsinore and portions of Moreno Valley and Beaumont.

In 1994, the Regional Board listed Canyon Lake on the 303 (d) list of impaired waterbodies due to excessive input of nutrients, low dissolved oxygen and pathogens. The source of these pollutants was listed as non-point sources. There are no traditional point source discharges of waste to Canyon Lake (*e.g.* publicly owned treatment works [POTWs], industrial facilities discharges). Storm water runoff, now considered a point source because of its regulation under the NPDES program, is the major contributor of nutrients to the Lake.

1.1 Brief History of Canyon Lake

After construction of the Railroad Canyon Reservoir dam by the Temescal Water Company, Corona Land Company developed the land surrounding Canyon Lake. The Canyon Lake Property Owners Association (POA) was formed in 1968. All lots at Canyon Lake were sold by 1975. The Lake and the fringe of land around it were owned by the Temescal Water Company, and leased to the POA for recreational purposes. Subsequently, the Elsinore Valley Municipal Water District (EVMWD) bought the Temescal Water Company, and in 1989 the EVMWD entered into a contract to acquire the Lake and these leases. The agreement between EVMWD and the Canyon Lake

POA requires that the minimum Lake elevation be kept at 1372 ft above sea level. The spillway elevation of the dam is at 1381.76 ft above sea level. In the last decade, EVMWD has supplemented the Lake with water imported from the Colorado River to maintain the required water level in Canyon Lake.

In December 1990, Canyon Lake was incorporated as a city. The City of Canyon Lake is a private and gated community, and use of the Lake is limited to residents.

In addition to recreational uses, Canyon Lake is also a source of drinking water. EVMWD draws the water from Canyon Lake (near the dam) and treats it at the Canyon Lake Water Treatment Plant located near the dam, before delivery to the District's customers. Water from Canyon Lake comprises approximately one quarter of the total water supply of the EVMWD service area (Julius Ma, EVMWD, oral communication).

1.2 Canyon Lake Beneficial Uses and Water Quality Objectives

The beneficial uses of Canyon Lake as identified in the 1995 Water Quality Control Plan for the Santa Ana River Basin (Basin Plan) are as follows:

- Municipal and Domestic Water Supply **(MUN)**
- Agriculture Water Supply **(AGR)**
- Groundwater Recharge **(GWR)**
- Body Contact Recreation – **(REC1)**
- Non Body Contact Recreation – **(REC2)**
- Warm Freshwater Aquatic Habitat – **(WARM)**
- Wildlife Habitat – **(WILD)**

The Basin Plan specifies both numeric and narrative water quality objectives for Canyon Lake that relate to nutrient impairment. These objectives are as follows:

- Algae – Waste discharges shall not contribute to excessive algal growth in receiving waters.

- Un-ionized Ammonium-N (UIA) – 0.822 mg/L

- Dissolved Oxygen – the dissolved oxygen content of surface waters shall not be depressed below 5 mg/L for waters designated **WARM.**

The Basin Plan also specifies a total inorganic nitrogen (TIN) objective for drinking water protection of 8 mg/L[1]. Given the eutrophication problems in Canyon Lake, Regional Board staff believes this value may not be protective of the WARM beneficial use and may need to be revised. The Basin Plan does not specify a phosphorus water quality objective for Canyon Lake. As will be discussed further, both nitrogen and

[1] TIN is the sum of nitrate, nitrite and ammonia forms of nitrogen.

phosphorus concentrations affect algae growth in Canyon Lake and, therefore, it may be appropriate for the Regional Board to consider developing both nitrogen and phosphorus objectives for the Lake to address eutrophication concerns.

2.0 Eutrophication of Canyon Lake – Summary of Existing Water Quality Data

The eutrophication processes discussed in great detail in the Lake Elsinore Nutrient TMDL Problem Statement (November, 2000) also apply to Canyon Lake. Briefly, eutrophication of a lake means that as nutrient input to the lake increases, the biological productivity of the lake increases accordingly. There are three stages in the lake eutrophication continuum - oligotrophy, mesotrophy and eutrophy. An oligotrophic lake has low nutrient input, low productivity, and very clear water. In a mesotrophic lake, nutrient levels start to increase, resulting in an increase in biological productivity. An eutrophic lake has high nutrient levels and high biological productivity. As a result of high algal productivity in an eutrophic lake, the turbidity of the lake is high, and the color of the water may turn green. The algal debris can also be washed to shore, causing an unsightly shoreline and offensive odor as the algae decomposes. The decomposition of the algal matter in the water column uses up the oxygen in the water, resulting in oxygen depletion that, in turn, can cause fish kills. The depletion of oxygen can also increase the concentration of soluble manganese and iron that, at high enough concentrations, may render the water unsuitable for drinking. Both manganese and iron are difficult to remove from drinking water supplies by the water treatment process.

Excessive nutrient input and high algae productivity has resulted in the impairment of beneficial uses of Canyon Lake including contact recreation (REC1), non-contact recreation (REC2), warm water aquatic habitat (WARM) and municipal drinking water supply (MUN). The following section summarizes the existing water quality data for Canyon Lake demonstrating the eutrophic status of the Lake.

2.1 Existing Water Quality Data for Canyon Lake

Very little water quality data on Canyon Lake, particularly nutrient data, were collected before the 1980s. During the period of 1983-1986, Regional Board staff collected water samples from Canyon Lake for various constituents as part of the Region’s monitoring and assessment program. On August 19, 1994, Earth Sciences Consultants measured temperature, dissolved oxygen and electrical conductivity at five stations in Lake Elsinore and three stations in Canyon Lake. The three stations in Canyon Lake, “Boom”, Buoy”, and “Intake”, were all in close proximity to the dam.

On July 10, 1996, the Santa Ana Watershed Project Authority (SAWPA) measured dissolved oxygen, water temperature, specific conductance, and pH profiling of Canyon Lake near the dam in order to compare Canyon Lake water quality with Lake Elsinore. The results were similar to those obtained by the Earth Sciences Consultants two years earlier. In July and October 1995 and January, April and July 1996, Black & Veatch collected water samples (one composite from the upper level and one composite sample from the lower level) from one station in Canyon Lake for conventional chemical constituents analysis.

Elsinore Valley Municipal Water District (EVMWD) has been monitoring the water quality of Canyon Lake since March 1996. A Hydrolab multiprobe has been used to measure the water temperature, dissolved oxygen and other parameters. These data are used by EVMWD to develop the water column depth profile to determine the appropriate depth for water withdrawal and also to determine when Lake “turn-over” occurs.[2] EVMWD also collected surface water samples from near shore locations for analysis of various constituents. EVMWD continues to monitor the physical and chemical characteristics of Canyon Lake at their treatment plant uptake points; however, the District disconnected the surface water quality monitoring since the Regional Board and stakeholders initiated the TMDL monitoring program (discussed below) in the summer of 2000.

In 1998, the U.S. Geological Survey began the National Water Quality Assessment (NAWQA) Study in the Santa Ana Watershed. One sediment core was taken in Canyon Lake to determine the sedimentation rate and to analyze for metals, organochlorine pesticides, and polyaromatic hydrocarbons. Riverside Flood Control and Water Conservation District also collected water quality data in the San Jacinto River watershed (1992-1999) as required by their National Permit Discharge Elimination System (NPDES) storm water permit. Most of the data collected by the Flood Control District were sporadic and not focused on studying eutrophication; however, the data do provide some understanding of the dynamics of Canyon Lake and the watershed.

Starting in May 2000, Regional Board staff and stakeholders began monitoring the water quality of Lake Elsinore and Canyon Lake, specifically for nutrients, as part of the TMDL development effort. During the summer months (June, July, August, and September), water samples are collected biweekly for nutrient analysis at four sampling stations, CL07, CL08, CL09 and CL10 (see Figure 2). Water samples are collected from three depths to characterize the vertical variation. Physical parameters such as temperature, dissolved oxygen, pH, conductivity, and turbidity are also measured at three feet intervals at the time of sample collection. The Regional Board’s nutrient TMDL monitoring program is ongoing and will last through 2002.

The results from the Regional Board monitoring program are consistent with data collected in previous studies. Because the Regional Board monitoring is more recent and more extensive than previous studies, the following section focuses on the Regional Board’s sampling results.

2.2 Physical Characteristics of Canyon Lake

[2] Lake turn-over typcially occurs in the fall as ambient air temperatures decrease, causing surface water temperatures to also decrease. As the surface water temperature decreases, the density of the water increases, and at some point, the surface water mixes with deeper cooler water.

Compared to Lake Elsinore, which is shallow and has a large surface area (3300 acres) with a rather flat lake bottom, Canyon Lake has a small surface area (500 acres) and steep banks. Water depth varies greatly depending on the location in the Lake. Table 1 is a summary of Canyon Lake's water depth and transparencies as indicated by Secchi depth[3] readings from the Regional Board's monitoring program. As shown in Table 1, the Lake is much deeper in the western fork of the Lake (over 50 feet near the dam), and is shallow in the eastern part (approximately 8 feet at the East Bay). A detailed bathymetric survey will be conducted by the University of California at Riverside in the fall of 2001 to map the Lake bottom elevation and to study the nutrient cycles in Canyon Lake.

Table 1. Canyon Lake Water Depth and Secchi Depth *

Sample site	Location Description	Total Depth (ft)	Secchi Depth (in)
CL-07	At Dam	50.00	38
CL-08	North Channel	27.00	48
CL-09	Canyon Bay	19.25	33
CL-10	East Bay	8.65	30

* The numbers listed are the mean of all measurements for each site as of November 2000.

The temperature profile of the Canyon Lake water column in August 2000 demonstrates that the Lake is thermally stratified in the summer. The most pronounced stratification occurs at the Dam (Figure 3a). The Lake water was stratified into three layers, with the top layer being warm (temperature as high as 30°C), less dense and saturated with oxygen. This top layer is called epilimnion, where photosynthesis occurs and algal productivity is high. The bottom layer is colder (15°C), denser and dark. The bottom layer is called the hypolimnion. Due to the absence of light and low temperatures, algal productivity is minimal in the hypolimnion, although the senescent and decomposing algal cells may settle there. In between the epilimnion and hypolimnion is the thermocline, where temperature and dissolved oxygen decrease dramatically. As shown on Figure 3a, at the Dam, the thermocline is at a depth of 15-24 feet.

As shown in Figure 3b, in the North Channel, the temperature and dissolved oxygen decreases at depths between 15 and 18 ft. However, the temperature only drops to 20°C near the Lake bottom (compared to 15°C at the Dam). The Canyon Bay Location (Figure 3c) has a similar profile. As shown in Figure 3d, at the East Bay sampling location, the water column seems to be well mixed. The differences in water

[3] Secchi depth is a measure of the clarity of water. The greater the Secchi depth reading, the greater the water clarity.

temperature, dissolved oxygen, and turbidity at the four sampling locations are due to the differences in water depth at the four sites. In the deep part of the Lake, such as at the Dam, thermal stratification developed and three layers are apparent. In the shallower part of the Lake, such as North Channel and Canyon Bay, the temperature decreases at certain depths and anoxia exists at the Lake bottom. For East Bay where the water depth is less than 10 feet, the water is mixed; temperature and dissolved oxygen are relatively constant throughout the water column.

Stratification of Canyon Lake disappears in the fall and winter when the Lake turns over. Figure 4 shows that the water temperature and dissolved oxygen are uniform throughout the water column in December 2000. Since the trends are the same for each sampling site, only data from two sites (CL-07 and CL-09) are shown (Figure 4).

2.3 Water Quality Data Related to Eutrophication

Although lake eutrophication is the response of an entire ecosystem to the levels of nutrients, several chemical constituents have been used to evaluate the eutrophic status of a lake. The United States Environmental Protection Agency (USEPA, 2000) suggests the use of nitrogen, phosphorus, *chlorophyll a*, Secchi depth, and hypolimnion oxygen saturation as lake eutrophication indices. In the 1970s, USEPA conducted a survey on eutrophication of lakes and reservoirs around the nation and developed a classification scheme for lake eutrophic status based on these parameters. Other chemical parameters have also been used for classifying eutrophic status. This section discusses these parameters for Canyon Lake and compares them to the USEPA classification scheme.

Dissolved Oxygen

Dissolved oxygen levels in Canyon Lake range from over-saturation at the surface to near zero at the thermocline (Figure 3). The low levels of dissolved oxygen near the thermocline were due to the decomposition of algal materials and the lack of mixing of water. Results from the Regional Board’s sampling program indicate that the water quality objective for dissolved oxygen of 5 mg/L is not being met at all locations or at all depths in the Lake. This may result in impacts to aquatic life, such as occasional fish kills (Paul Beaty, consultant to Canyon Lake POA, oral communication).

The low dissolved oxygen levels have also resulted in the release of high levels of soluble manganese and iron from the sediment. EVMWD shuts down the water treatment plant when the manganese concentration is above 0.45 mg/L. The anoxic condition in the hypolimnion could also facilitate the release of phosphorus and ammonia from the sediment, both of which are available for algal growth when the Lake turns over.

Chlorophyll a

Chlorophyll a is a pigment in most algae and green plants and has been used as an indicator of algae biomass. USEPA has recommended that a lake with *chlorophyll a* greater than 10 ug/L be considered eutrophic. The *chlorophyll a* level in Canyon Lake ranges from below detection limit (1 ug/L) to 180 ug/L, with a median of 17.6 ug/L (Table 2). *Chlorophyll a* concentrations at all sites in Canyon Lake stay low in the summertime and then increase in the fall-winter season when the Lake turns over (Figure 5). During summertime, the Lake is stratified so that the nutrients in the hypolimnion are not available for algae uptake; meanwhile the nutrients in the epilimnion can be used for algal productivity, but are in limited supply. When the Lake turns over, the hypolimnion provides a new source of nutrients that can cause an increase in algal productivity. Since this usually occurs in the fall/winter period when temperatures are lower and days are shorter, algal responses and growth are not as likely to result in severe algal blooms. Such a phenomenon is quite different from Lake Elsinore, which usually has algal blooms in the summertime when the Lake becomes anoxic. Because Lake Elsinore is much shallower and does not stratify during the summer, nutrients released from the sediments are readily available for algal growth at all times. Although Canyon Lake receives more nutrients from the San Jacinto River and Salt Creek Watersheds than Lake Elsinore, algal blooms and fish kills are not as severe as those that occur in Lake Elsinore. The greater water depth in Canyon Lake prevents the nutrients from the sediment from becoming available for algal growth in the photic zone.

Because of the algal biomass increase during the Canyon Lake turn-over period, EVMWD typically stops operation of the water treatment plant for about two weeks because algal cells can clog the filters in the treatment plant. Occasionally, copper sulfate is applied by the Canyon Lake POA and EVMWD staff as an algaecide during algal blooms to improve water clarity.

Table 2. Canyon Lake Nutrient Water Quality Data Summary

(Regional Water Quality Control Board, May 2000 through May 2001)

	Ortho-P	Total P	*Chlorophyll a*	TKN	Nitrate as N	Nitrite as N	Ammonium-N	TKN/TP ratio
	(mg/L)	(mg/L)	(ug/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	
Minimum	ND	0.06	ND	ND	ND	ND	ND	2
Maximum	1.61	1.9	180	7	0.38	ND	5.4	15.7
Median	**0.18**	**0.25**	**17.6**	**1.1**	**ND**	**ND**	**0.14**	**7.8**
Mean*	NA	0.46	NA	NA	NA	NA	NA	7.97
Std. Dev.	NA	0.59	NA	NA	NA	NA	NA	4.2
25 percentile	0.02	0.12	8.28	0.9	ND	ND	ND	4.4
75 percentile	0.61	0.59	35	1.8	ND	ND	0.4	10
# of data points	116	129	64	139	139	130	143	46
D.L.	0.02	0.02	1	0.5	0.1	0.1	0.1	
Eutrophic Lake**		**>0.02**	**10**					

ND = Non-detectable
NA = Not applicable
TKN = Total Kjeldahl Nitrogen, a sum of ammonia-N and organic N.
* Mean values of NA indicate most analytical results below detection limits (therefore mean not calculated)
** According to USEPA (2000)

D.L = detection limit

Phosphorus and Nitrogen

The phosphorus and nitrogen cycles in lake systems are discussed in detail in the Lake Elsinore nutrient TMDL problem statement. Both phosphorus and nitrogen are essential nutrients for algal growth. There are several forms of phosphorus and nitrogen in the water column. Soluble reactive phosphorus (measured as ortho-phosphate in the lab) and total phosphorus are present in varying concentrations. Soluble reactive phosphorus can be taken up by algae directly from the water column. Total phosphorus includes the soluble form and the particulate form suspended in the water column (including algal cells). In Canyon Lake, soluble phosphorus ranges from below the analytical detection limit (0.012 mg/L) to 1.65, mg/L with a median of 0.18 mg/L. The concentrations of total phosphorus range from 0.06 to 1.90 mg/L, with a median of 0.25 mg/L and a standard deviation of 0.59, reflecting a great variability of phosphorus concentrations in Canyon Lake (Table 2).

Nitrogen forms analyzed include nitrate, nitrite, ammonium, and total kjeldahl nitrogen. Total kjeldahl nitrogen is the sum of ammonium-nitrogen and organic nitrogen. In Canyon Lake, nitrate-nitrogen and nitrite-nitrogen are typcially below analytical detection limits (0.1 mg/L) (Table 2). Ammonium-nitrogen is the main form of inorganic nitrogen in Canyon Lake. The values of ammonium-nitrogen range from non-detectable to 5.4 mg/L, with a median of 0.14 (Table 2). Total kjeldahl nitrogen concentrations ranged from non-detect to 7.0 mg/L, with a median of 1.1 mg/L. It can be postulated that the majority of the nitrogen is in the organic form (amino acid, proteins, nucleic acid, etc.).

The ratio of total nitrogen (TN) to total phosphorus (TP) has been used to estimate which of the two nutrients is the limiting factor for algae growth. If the ratio is greater than 10-15, then phosphorus is considered the limiting nutrient; if the ratio is less than 10, nitrogen is considered the limiting nutrient. The ratio varies temporally and spatially for most waterbodies, suggesting the limiting nutrient for algal growth changes through time and location. For Canyon Lake, since nitrate and nitrite are mostly below detection limits, total kjeldahl nitrogen (TKN) represents total nitrogen. The TKN/TP ratio for Canyon Lake is variable, ranging from 2 to 15.7, with a median of 7.8 and a standard deviation of 4.2 (Table 2). The ratio does vary spatially and temporally in Canyon Lake. At sampling sites CL07 (at Dam) and CL08 (North Channel), phosphorus seems to be the limiting nutrient in the summer; in the fall and winter, nitrogen becomes the limiting nutrient (Figure 6a). Such a trend holds true for site CL09 (Canyon Bay) as well. At site CL10 (East Bay) where the water is very shallow, nitrogen seems to be the limiting nutrient most of the time (Figure 6b).

At various times and locations, both phosphorus and nitrogen can be the limiting nutrient in Canyon Lake; therefore, both nutrients should be controlled in order to control excessive algal growth.

Chemical Stratification

As discussed in the previous section, Canyon Lake is thermally stratified in the summer, mixes in the fall and stays mixed through the winter. During late spring, the Lake stratifies again. This thermal stratification also results in the chemical stratification of constituents such as ortho-phosphate-P, total phosphate-P and total kjeldahl nitrogen during the summertime (Figure 7a, b, and c). When the lake turns over, the chemical concentrations throughout the water column become uniform until stratification occurs again in the spring or summer. Figure 7a and 7b illustrate the correlation of high *chlorophyll a* during the lake turnover at Canyon Lake Dam and Canyon Bay. Canyon Lake at the East Bay sampling location does not stratify thermally or chemically, as shown in Figure 7d.

Trophic State Index

The Trophic State Index (TSI) was developed by Carlson (1974) to normalize the distribution of algal biomass measured by Secchi disk transparency (m), *chlorophyll a* concentration (mg/m^3), and total phosphorus concentration (mg/m^3). The TSI values have been used as a classification scheme to describe the eutrophic status of a lake in the eutrophication continuum. The calculation of the TSI value by Carlson's method is the following:

$$TSI = 30.6 + 9.81 * \ln(\textit{chlorophyll a}, \text{ in } mg/m^3)$$

$$TSI = 60 - 14.41 * \ln(\text{SD, Secchi disk readings, in m})$$

$$TSI = 14.42 * \ln(\text{TP, total phosphorus, in } mg/m^3)$$

Brezonik (1984) used total nitrogen as well as total phosphorus, *chlorophyll a* and Sechhi depth to calculate sub-indices and integrated them into an overall TSI to be used for phosphorus limited, nitrogen limited, or nutrient balanced lakes. The equation for the TSI index calculated from total nitrogen (TN) is the following:

$$TSI = 59.6 + 21.5 * \ln(\text{TN, in mg/L})$$

Most of the oligotrophic lakes measured had a TSI below 40, mesotrophic lakes had a TSI between 35 and 45, while most eutrophic lakes had a TSI greater than 45. The TSI values for Canyon Lake range from 58 to 108 (Table 3), clearly indicating eutrophic/hypereutrophic status.

Table 3 Carlson's Trophic Status Index Values for Canyon Lake

	TSI (TP)	TSI (chla)	TSI(SD)	TSI (TN)
Mean	88.41	NA	60.90	NA
Median	79.62	58.73	61.29	61.65
Minimum	59.04	NA	52.56	NA
Maximum	108.87	81.54	67.87	101.44

NA = not applicable
For Hypereutrophic lakes, TSI > 60

It is important to note that the nutrient concentrations of Canyon Lake are higher than Lake Elsinore. However, the response of the Canyon Lake to nutrient input is quite different from Lake Elsinore. For example, the dominant algal species in Canyon Lake are flagellate-green and green algae. In Lake Elsinore, blue-green algae are the dominant species, especially in the summertime. In order to simulate algal response to various nutrient load scenarios, to nutrient loads of Canyon Lake and Lake Elsinore, surface water quality modeling will be conducted for both lakes.

3.0 Canyon Lake Nutrient TMDL – Problem Statement/Numeric Targets

As discussed in the previous section, the water quality problems of Canyon Lake arise from eutrophication. The eutrophic condition means that the Lake is enriched with nutrients (phosphorus and nitrogen), resulting in high algal productivity. The decay of dead algae produces offensive odors and an unsightly lakeshore, adversely affecting use of the Lake for water-contact and non-contact recreational purposes (REC1 and REC2). In addition, the high amount of algal cells causes high turbidity in the Lake, making the water an uninviting murky green color at times. Depleted oxygen levels can result in fish kills, adversely affect the warm water aquatic habitat beneficial use (WARM). Both low oxygen levels that result in increased manganese and iron levels in the water column, and high algal productivity necessitates periodic shutdown of the Canyon Lake water treatment plant, adversely affecting the municipal drinking water supply (MUN) use of the Lake.

As a result of the algae blooms and depletion of oxygen in Canyon Lake and the adverse impacts of these conditions on beneficial uses, in 1994, the Regional Board placed Canyon Lake on the Clean Water Act Section 303(d) list of impaired waterbodies. For any waterbody listed as impaired, federal law requires that a total maximum daily load (TMDL) be established to address the impairment.

Pursuant to federal TMDL requirements, quantifiable and measurable numeric targets that will ensure compliance with water quality standards (beneficial uses, water quality objectives and anti-degradation policy) must be established in the TMDL (USEPA, 1999). For Canyon Lake, the municipal water supply (MUN), warm water aquatic habitat (WARM) and water contact and non-water contact recreation (REC1 and REC2) are the beneficial uses that are impaired by the high levels of nutrient input. The TMDL and its numeric targets must be structured to assure protection of the MUN, WARM, REC1 and REC2 beneficial uses and attainment of the nutrient related water quality objectives specified in the Basin Plan (see Section 1.2).

It is proposed in this document that numeric targets for dissolved oxygen, *chlorophyll a*, total phosphorus and total inorganic nitrogen be included in the Canyon Lake nutrient TMDL. If these numeric targets are met, then the water quality standards for Canyon Lake will be achieved. It is also important to note that when Canyon Lake spills, this water is a source for Lake Elsinore. The nutrients in Canyon Lake could contribute to the eutrophication of Lake Elsinore. Therefore, the numeric targets for Canyon Lake should be stringent enough to protect the downstream waterbody. Staff's initial assessment of appropriate numeric targets for the Canyon Lake nutrient TMDL is reflected below. However, with additional data that are to be collected in the next year, staff may propose additional numeric targets or revise those discussed within this document.

Dissolved Oxygen

The Basin Plan specifies a dissolved oxygen water quality objective of:

The dissolved oxygen content of surface waters shall not be depressed below 5 mg/L for waters designated as WARM.

The proposed Canyon Lake nutrient TMDL numeric target for dissolved oxygen is as follows:

- Daily average dissolved oxygen be 5 mg/L at the hypolimnionetic[4] zone, when the lake stratifies; and

- Average dissolved oxygen over depth should be no less than 5 mg/L when the lake is well mixed from top to bottom.

Further study is required to establish the relationship of hypolimnionetic oxygen level and the concentration of manganese.

Chlorophyll a

Currently, there are insufficient data to determine the *chlorophyll a* concentration that would result in no excessive algal blooms in Canyon Lake. For an interim goal, staff proposes that, based on the USEPA *chlorophyll a* values for eutrophic lakes, the interim target for *chlorophyll a* for Canyon Lake should be as follows (see Table 2):

[4] The lower, colder water zone in a stratified lake.

- *chlorophyll a* concentrations shall be no greater than an annual mean of 10 ug/L, and a daily peak of 20 ug/L.

As more data become available that allow a better relationship between *chlorophyll a* concentrations and algal blooms to be developed, the numeric target will be re-evaluated.

Total Phosphate as P

The ratio of total phosphorus to *chlorophyll a* in Canyon Lake scatters around 5. Using a *chlorophyll a* target of 10 ug/L, the annual average of total phosphate as P should not exceed 0.05 mg/L (50ug/L).

Total Nitrogen

Assuming an ideal ratio of total nitrogen to total phosphorus to be 10 to 1(nutrient balanced), the annual average of TN should be 0.5 mg/L.

4.0 Regional Board Planned Activities for TMDL Development

Regional Board staff initiated the Lake Elsinore/Canyon Lake nutrient TMDL development process in the fall of 1999. As shown in Table 4, development of the TMDL will continue through 2003. One of the first steps in developing the TMDL is to determine all of the nutrient sources and the nutrient loads associated with each source. In an effort to obtain the source and loading information, Regional Board staff obtained monitoring data from various agencies in the Canyon Lake/Lake Elsinore watershed. Unfortunately, nutrient sources were not quantified in any of the reports or data reviewed. These data are critical for TMDL development. Therefore, Regional Board staff, in coordination with watershed stakeholders, have developed and implemented an extensive watershed-wide monitoring program. To develop the monitoring program, Board staff evaluated the watershed to determine potential inputs to Canyon Lake, which include confined animal facilities (including dairies, non-dairy sites such as duck ranches and chicken ranches, sites where manure is disposed to land but not for the purpose of growing crops, and crop land located within the dairy property for the purpose of growing crops), urban uses (including residential, commercial and industrial), irrigated agriculture, imported water, and open space. The Lake Elsinore/San Jacinto Watershed Joint Power Authority (JPA[5]) has assisted the Regional Board in the monitoring program by providing funding support. Stream flow gauging stations along tributaries and the main stem of the San Jacinto River have been installed to measure

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[5] JPA members include City of Lake Elsinore, City of Canyon Lake, Elsinore Valley Municipal Water District, SAWPA, and the County of Riverside. Several lake management practices have been proposed for Lake Elsinore and Canyon Lake, including addition of recycled water to Lake Elsinore, treatment wetland expansion, aeration, fishery management, and metal salt addition. Canyon Lake aeration and partial dredging have also been proposed.

flow. Both water quality data and the stream flow will be used to calculate the total nutrient loads to Lake Elsinore and to Canyon Lake, and the nutrient loads from various sources mentioned above. The Regional Board staff have also been conducting in-lake water quality monitoring since May 2000 to evaluate the current nutrient cycling processes and to determine the Lakes' response to nutrient loads from the watershed.

Monitoring began in the summer of 2000 and will continue though 2002. Once nutrient sources have been identified and quantified, the proposed TMDL and allocations for all sources will be developed. The proposed TMDL will also include an implementation program and a monitoring program for TMDL compliance evaluation.
Regional Board staff have also contracted with the University of California at Riverside to conduct a number of studies needed for TMDL development, including a bathymetric survey of Canyon Lake, an evaluation of the sediment chemistry to determine the nutrient release rate from Lake sediment, development of a Canyon Lake nutrient budget, and development of a Lake water quality model to predict the Lake response to nutrient loads from the watershed and Lake sediment.

Due to the high variability of hydrologic conditions of the San Jacinto River Watershed, modeling is required to simulate all scenarios and to determine the nutrient loads from all sources under each scenario. The watershed model will also determine if proposed nutrient load allocations for San Jacinto watershed will achieve the proposed numeric targets for both Canyon Lake and Lake Elsinore. To develop the watershed model, the Santa Ana Watershed Project Authority (SAWPA) has obtained funding through the federal 205(j) grant program. Work to develop the watershed model is expected to start in October 2001.

Regional Board staff also realize that the implementation of a TMDL or other water quality improvement programs should occur in the context of a comprehensive watershed management plan. SAWPA has obtained funding under Proposition 13 to develop a San Jacinto Watershed Management Plan. The effort will be initiated in the next few months.

Regional Board staff convened a technical TMDL workgroup to assist staff in the development of the nutrient TMDL. The workgroup includes representative from the City of Lake Elsinore, the City of Canyon Lake and other watershed municipalities, Riverside County Flood Control and Water Conservation District, the County of Riverside, Elsinore Valley MWD, SAWPA, Eastern MWD, San Jacinto Resource Conservation District, dairy industry representatives (Milk Producers Council and Western Dairymen Association), The Farm Bureau, University of California at Riverside, and the public. The workgroup has been instrumental in assisting Regional Board staff in the development of the TMDL monitoring program, providing input on the proposed numeric targets, and serving as the critical nexus for coordinating all of the various studies, modeling efforts, etc. being conducted in the watershed. Regional Board staff will continue to meet with and solicit input from the TMDL workgroup on a regular basis throughout the TMDL development process. Staff believes that it is important to coordinate the TMDL development activities with the activities of other agencies in the watershed because some or all of the Lake restoration alternatives being considered may be included in the implementation plan for both the Canyon Lake and Lake Elsinore nutrient TMDLs.

Finally, Board staff anticipates providing an additional status report to the Regional Board in the summer of 2002 and bringing a proposed Canyon Lake/Lake Elsinore nutrient TMDL for Regional Board consideration in 2003/2004.

Table 4 LAKE ELSINORE WATERSHED – NUTRIENT TMDL DEVELOPMENT SCHEDULE

MAJOR ACTIVITIES	2000			2001												2002												2003											
	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Stakeholder Meetings	X	X		X		X		X		X		X		X		X	X	X		X		X		X	X	X		X	X	X		X	X	X	X	X	X	X	
Formulate Problem Statement													X																										
Identify Numeric Targets													X																										
Evaluate existing data													X																										
Conduct additional data collection (source analysis, modeling, allocation evaluation)																													X										
Develop Implementation Plan																													X										
Conduct Board workshops																																		X		X			
Conduct Board Hearing																																						X	

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The Recycled Water Task Force. 1997. Recycled Water for Lake Elsinore: Public Acceptance Issues and Recommendations.

U.S. EPA. 1990. The Lake and Reservoir Restoration Guidance Manual. EPA 440/4-90-006.

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Figure 1. Map of the San Jacinto Watershed

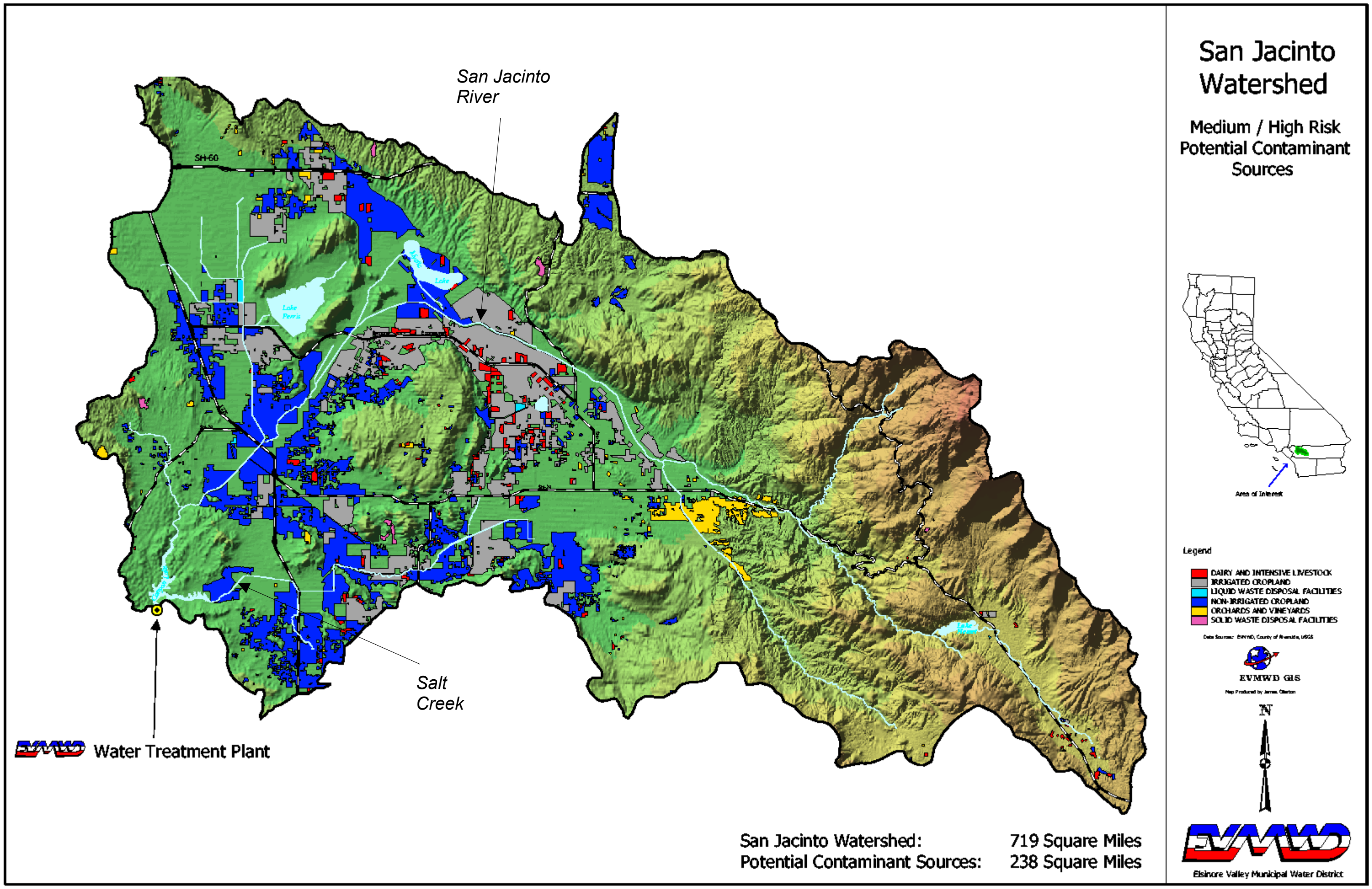
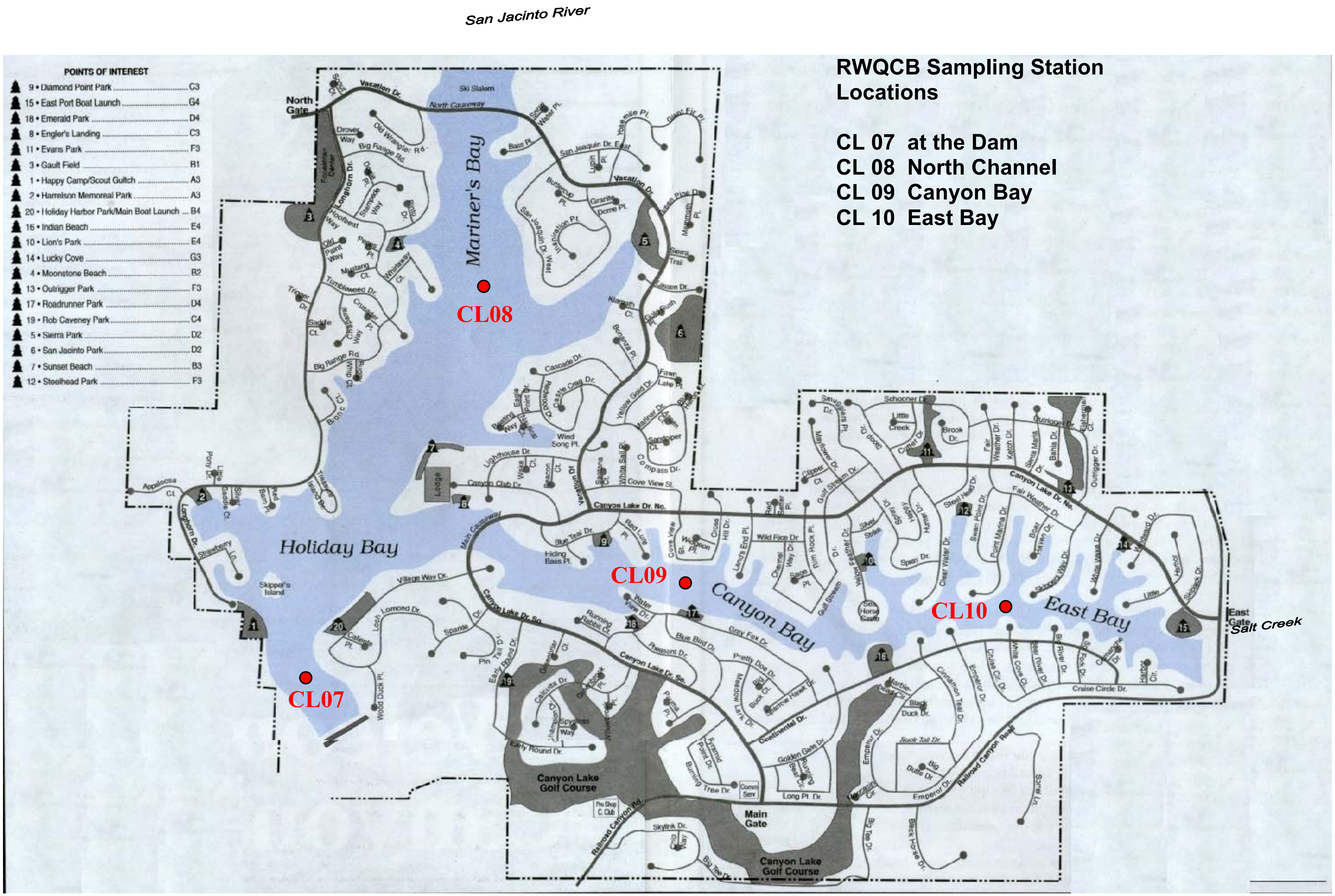
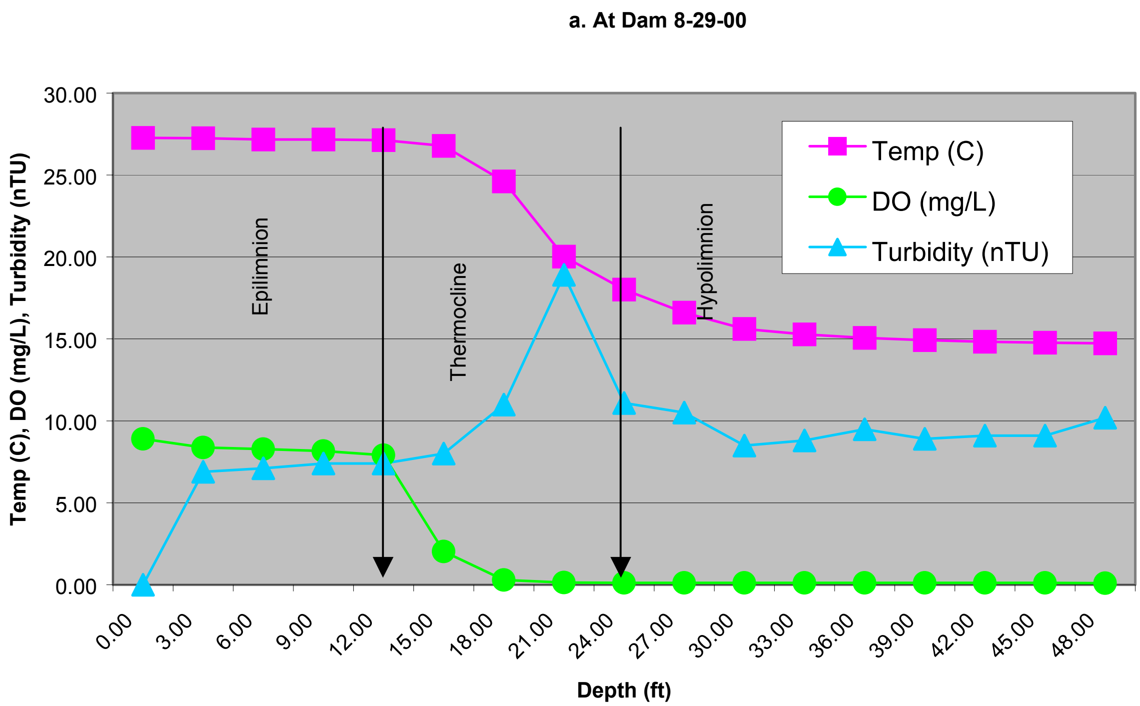


Figure 2. Map of Canyon Lake and Vicinity





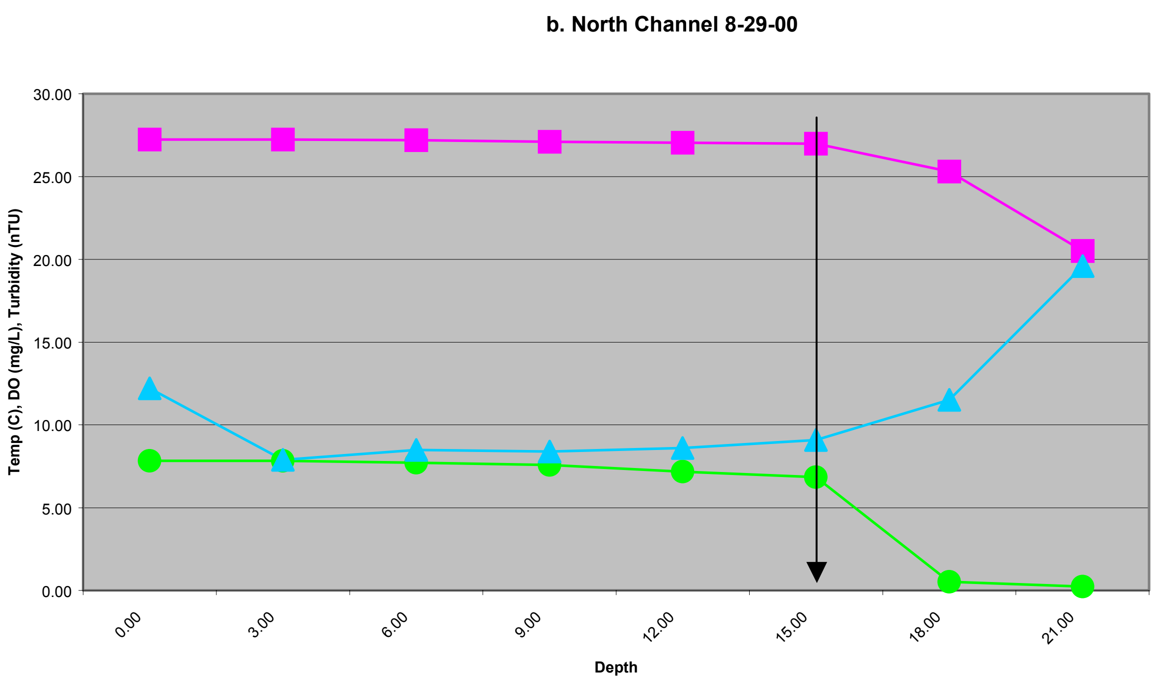
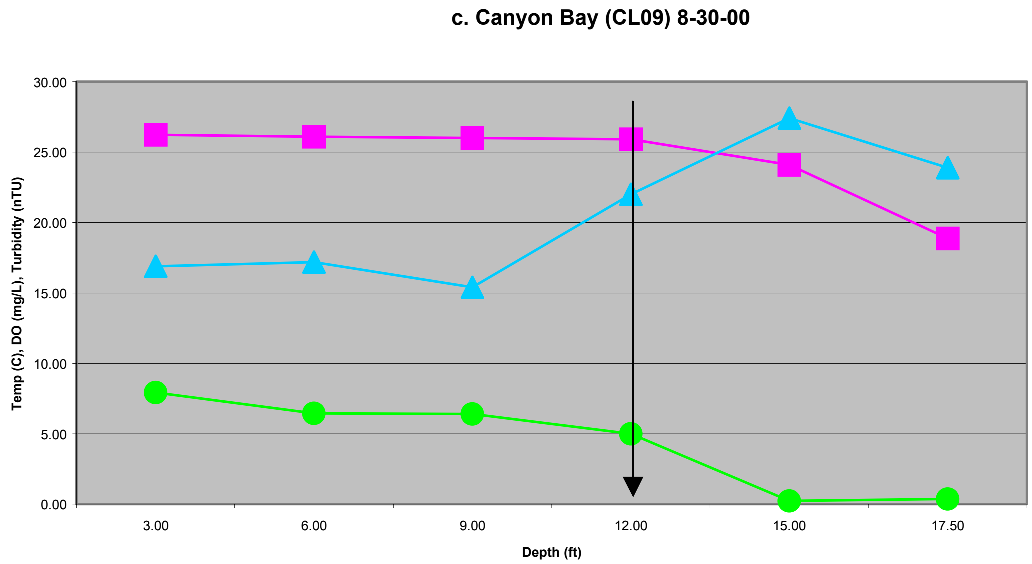


Figure 3a and 3b

Summer Stratification of Canyon Lake – Temperature, DO, and Turbidity Profiles at four monitoring stations in Canyon Lake.



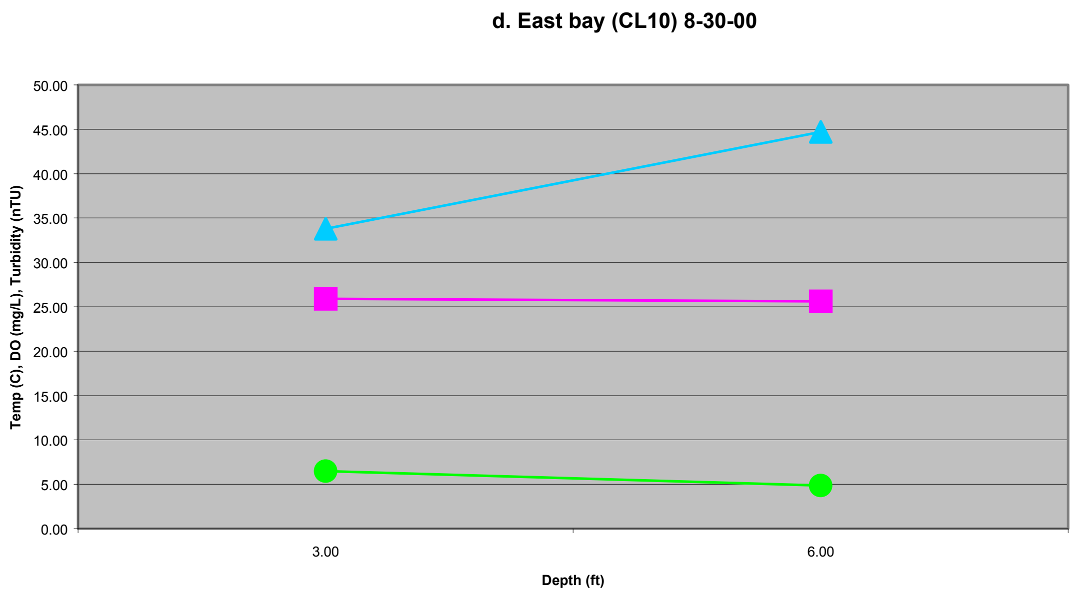


Figure 3c and 3d

Summer Stratification of Canyon Lake – Temperature, DO, and Turbidity Profiles at four monitoring stations in Canyon Lake.

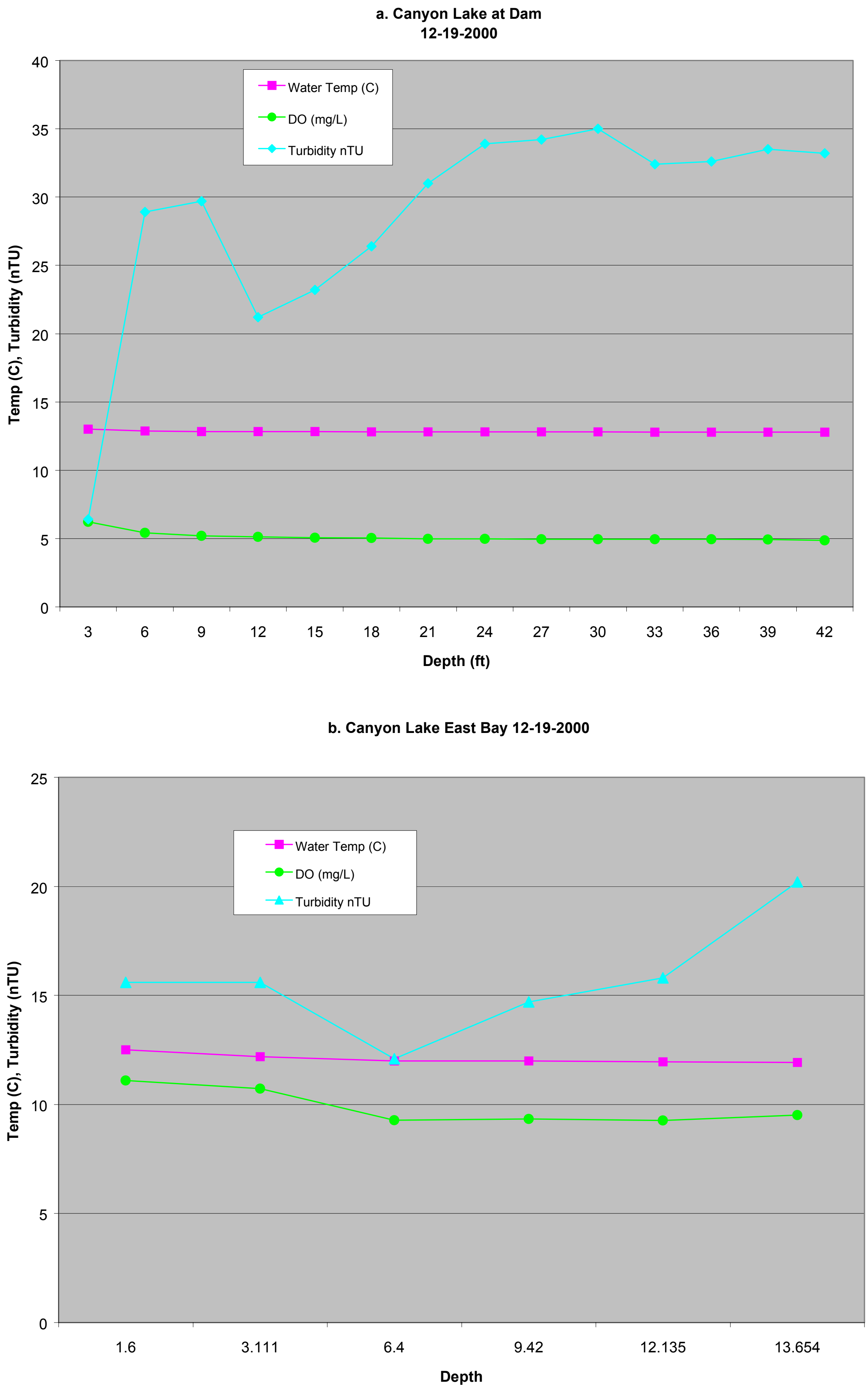


Figure 4. Canyon Lake Fall and Winter Turnover.

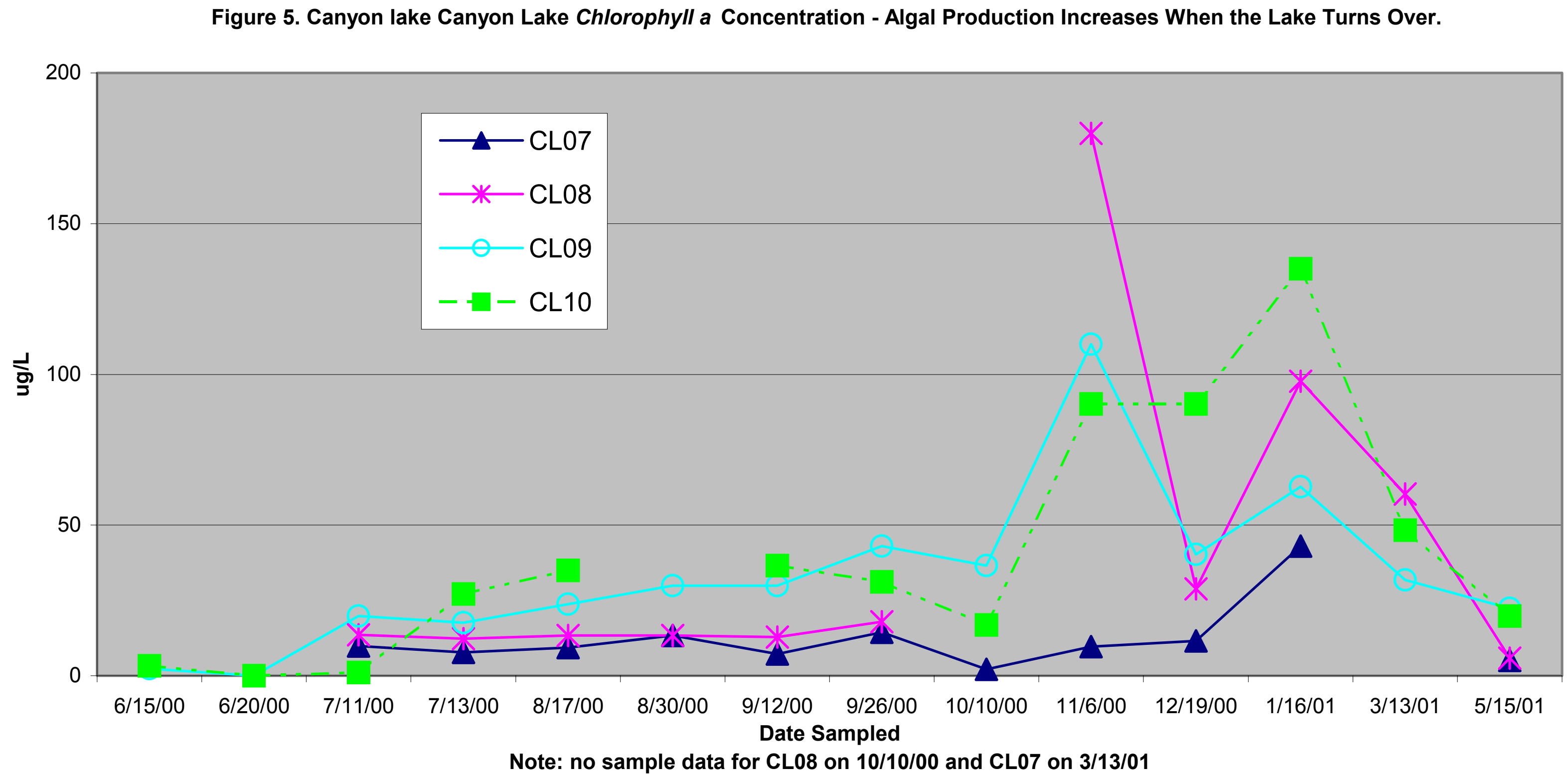
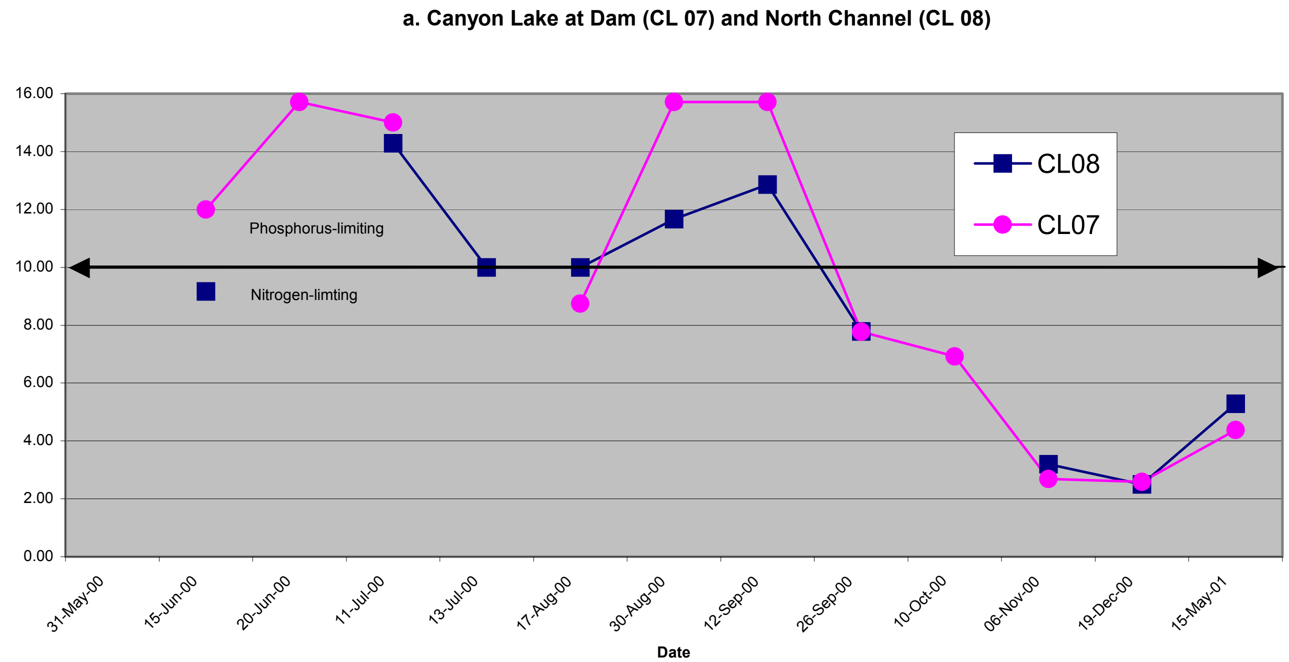


Figure 5. Canyon Lake *Chlorophyll A* Concentration – Algal Production Increases When The Lake Turns Over.



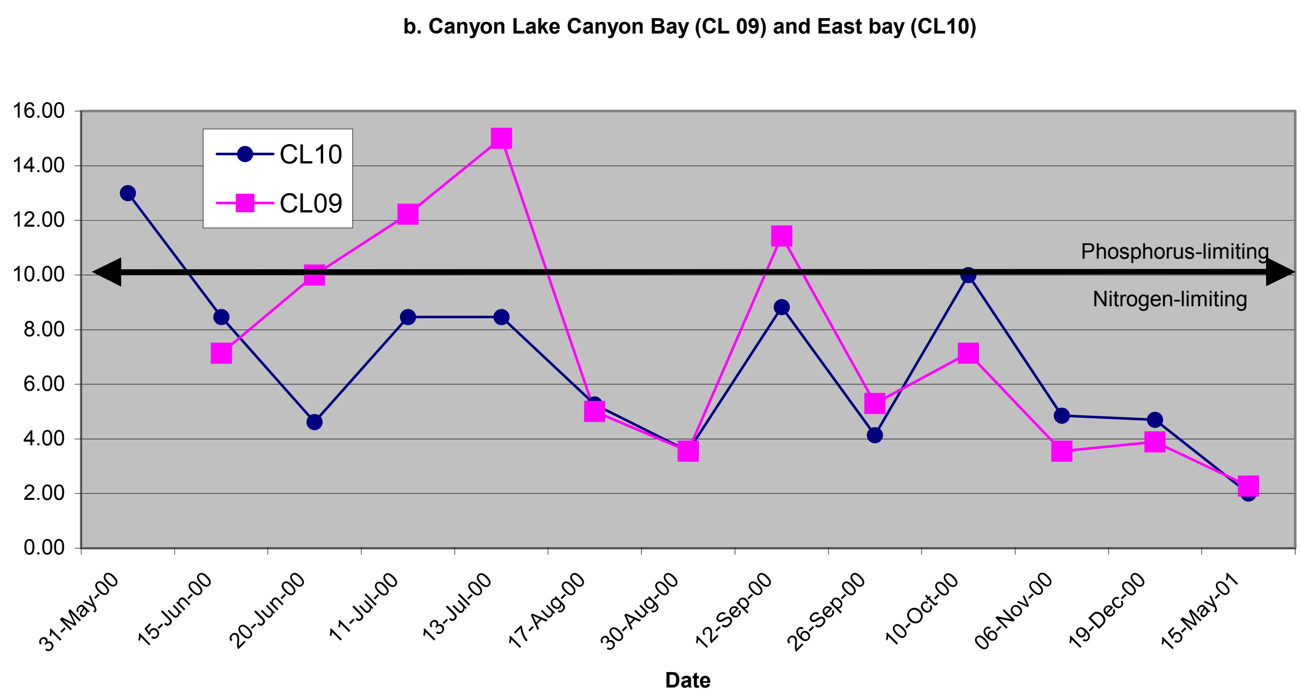
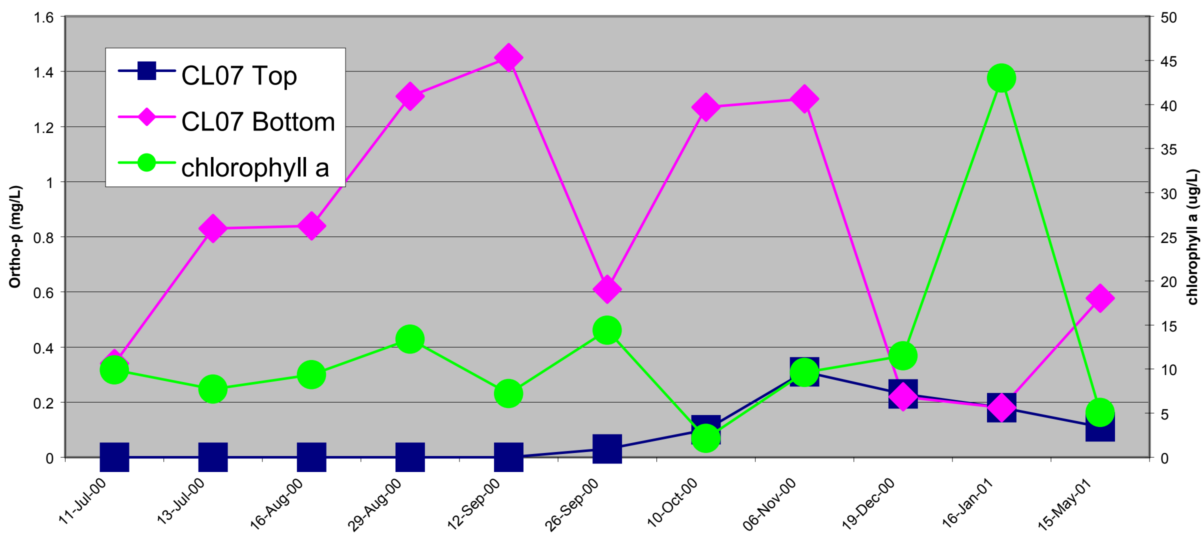


Figure 6. Total Kjeldahl Nitrogen (TKN) to Total Phosphorus (TP) Ratios for Canyon Lake Surface Samples

a. Canyon Lake at Dam (CL 07) - Ortho-P and *Chlorophyll a*



b. Canyon Lake Canyon Bay (CL 09) - ortho-P and *Chlorophyll a*

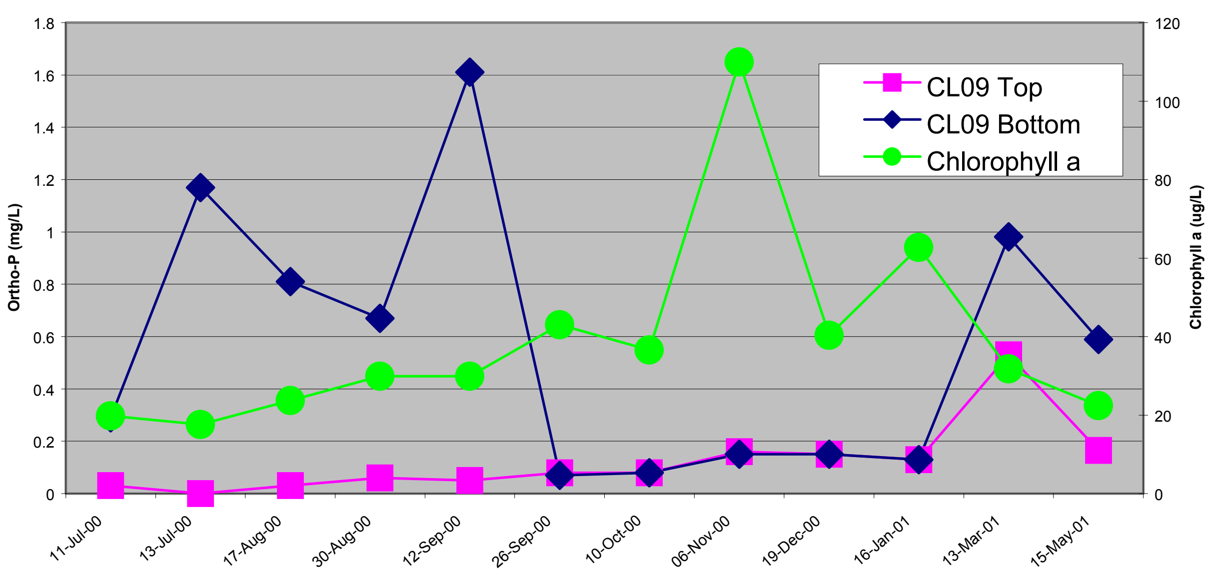
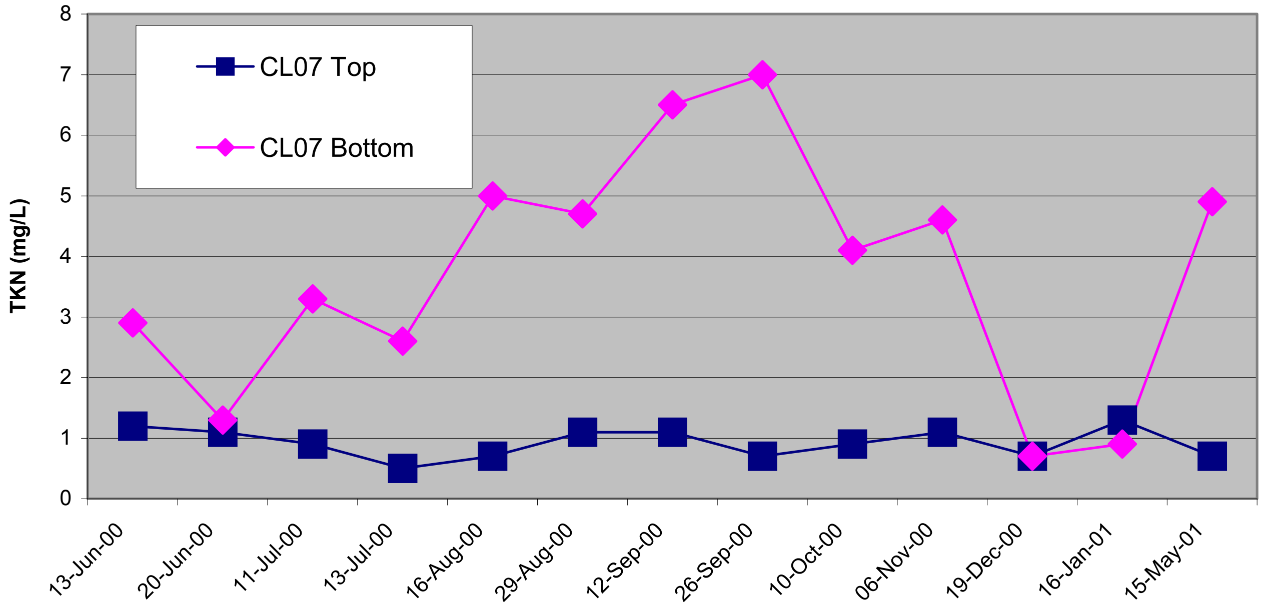


Figure 7a, b. Canyon Lake Chemical Stratification

c. Canyon Lake at Dam (CL 07) - Total Kjeldahl Nitrogen (TKN)



d. Canyon Lake East Bay - Total Phosphorus (TP)

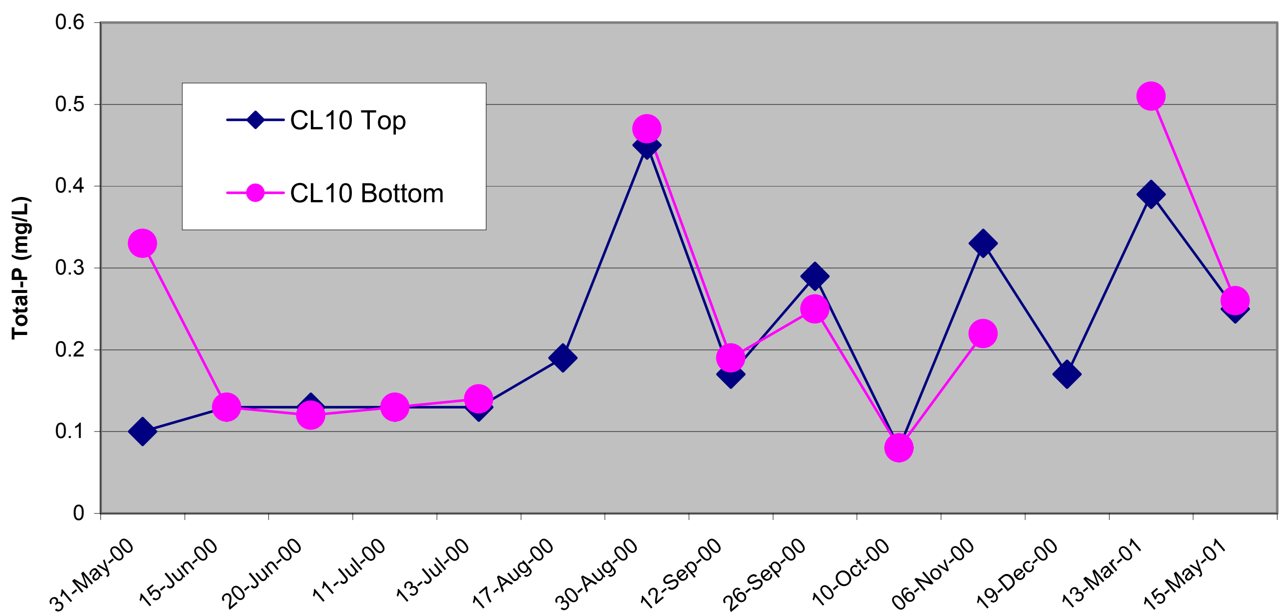


Figure 7c, d. Canyon Lake Chemical Stratification